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NANOSECOND LIGHT SOURCES FOR GAIN STABILIZATION

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ABSTRACT

Three fast light sources, a corona lamp, an argon lamp, and a high-pressure (190-mm Hg) neon lamp, were tested as possible sources for injecting a stable light pulse into a photomultiplier tube and thus stabilize the entire photomultiplier system.

The commercial corona lamps tested gave a nearly ideally shaped light pulse but were too unstable in light output for use as a standard source. The argon-lamp system showed good stability, but the light pulse has a long, low-amplitude tail which introduces difficulties in high-gain systems. The neon lamp appears to be the most promising source, preliminary tests showing a suitable pulse shape, output, and duration. The stability of the neon lamp was observed to be much better than that of the corona lamp, and tests are planned to determine whether it is superior to that of the argon lamp.

Note:
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It is well known that the gain of photomultiplier tubes changes with time, temperature, count rate, and magnetic field. The author has observed gain changes as large as 35% in scintillation spectrometers. Although the photomultiplier is the most likely source of gain shift in a given experiment, it cannot be assumed that the amplifiers and the pulse-height analyzer are completely stable, particularly if data must be accumulated over long time periods. However, the gain of a complete system can be stabilized by injecting a stable light pulse into the photomultiplier and using this signal as reference in a feedback loop to maintain constant gain. Three fast-light lamps were tested as possible sources for such a pulse: a corona lamp and an argon lamp that were developed at Lawrence Radiation Laboratory[1,2] and a neon lamp.

The high-voltage pulse generator used in the experiment was a Huggins 961 S. The light pulse shape and intensity were measured by a 56AVP photomultiplier tube, which has a rise time of approximately 2 nsec. Pulse shapes shown are voltage pulses across a 50-ohm anode load. Quoted rise and fall times were not corrected for the intrinsic limitations of the photomultiplier. Since fast-rising high-voltage pulses are required to excite the light sources, electrical shielding is no trivial problem. Double-shielded or solid-shielded cable was used to correct the pulse generator to the light source.

It is important that the housing for the light source be constructed of a good electrical conductor with the aperature as small as is consistent for necessary light output and that the photomultiplier be well shielded since corrections from the pin base to the dynodes form good resonant circuits.

Corona Lamp

The corona lamp developed at Lawrence Radiation Laboratory consists of a junction between a barium titanate bead and a small tungsten wire.

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[1] T. G. Innes and Q. A. Kerns, A Pulsed Nanosecond Light Source, UCRL-9726 (1961).

[2] Q. A. Kerns and R. F. Tusting, Constant-Amplitude Light-Flash Generator for Gain Stabilization of Photosensitive Systems, UCRL-10895 (July 18, 1963).

This structure is enclosed in a glass bulb and filled with approximately 1/2 atm of hydrogen gas. Due to the very high dielectric constant of the barium titanate, field emission can occur at relatively low voltages. The electrons produced initiate a discharge in the hydrogen gas. The discharge ceases soon after removal of the driving pulse; hence the device is capable of producing very short pulses of light.

Tests of a commercial version of this lamp, however, have been somewhat disappointing.[3] In order to achieve the best rise and fall of the light pulse, it is necessary to drive the lamp with a rectangular positive-going pulse. The full width at half maximum (FWHM) of the light pulse is slightly greater than the width of the driving pulse. The minimum driving pulse requirement is a 500-V 2-nsec wide pulse. Figure 1 shows the variation of the peak light intensity as a function of the input pulse amplitude. (Calculations were based on cathode sensitivity and gain data supplied by the manufacturer for the particular tube used.) Light output for a given input may vary by a factor of 3 between any two bulbs. Figure 2 shows the pulse shape at the anode of a 56AVP tube for a 7-nsec driving pulse. The spread in pulse height is more than twice as large as that predicted by photomultiplier statistics. Initial tests of new bulbs show a spread in pulse height as good as that quoted by Kerns[2] (approximately 6%). However, after several hours of operation the amplitude spread deteriorates to 20-30%. Although the shape of the light pulse is nearly ideal, the lack of stability eliminates the use of this lamp as a reference light source.

Argon Lamp

The argon light source was developed at Lawrence Radiation Laboratory as a microsecond-duration light pulser, and uses a commercial argon lamp (AR-4 or AR-3). The lamp is biased so that approximately 1μA of current flows through it continuously. A high-voltage rectangularly shaped pulse is applied across the lamp to produce a pulse of light. Figure 3 is an electric schematic of the argon light source unit. Pulse widths between 5 and 20 nsec and amplitudes (positive-going) between 700 and 2400 V

[3] Pek 118, Pek Laboratories, Inc., Palo Alto, California.

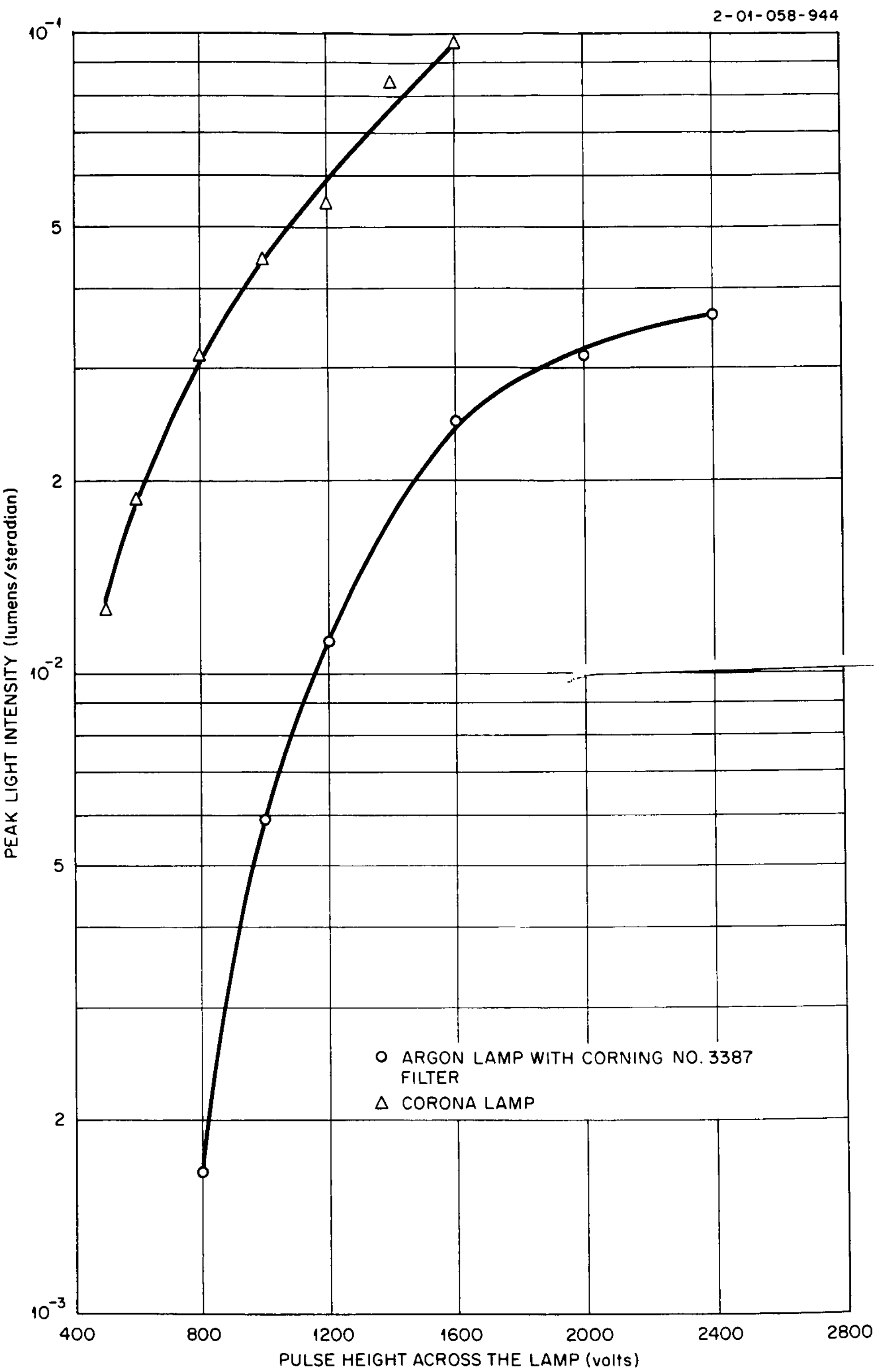

Fig. 1. Peak Light Intensity vs Input Pulse Height.

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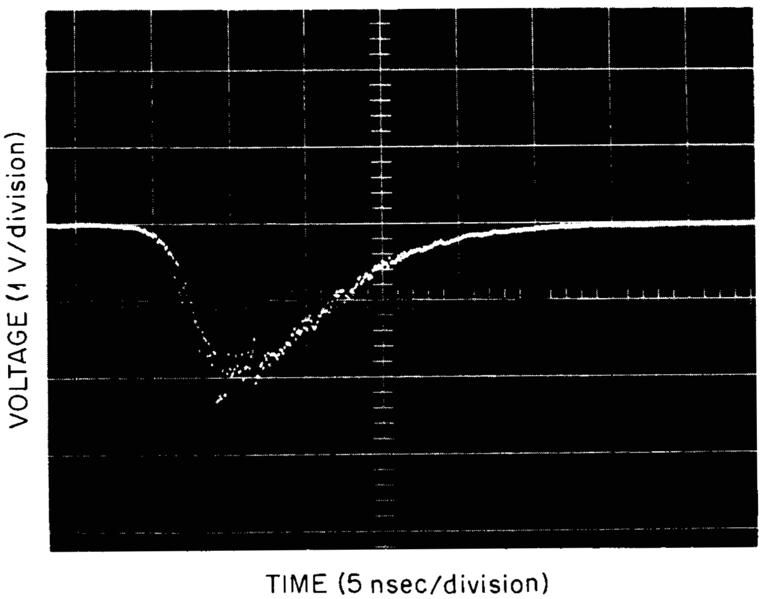

Fig. 2. Corona Lamp Pulse Shape at Anode of a 56AVP Photomultiplier Tube.

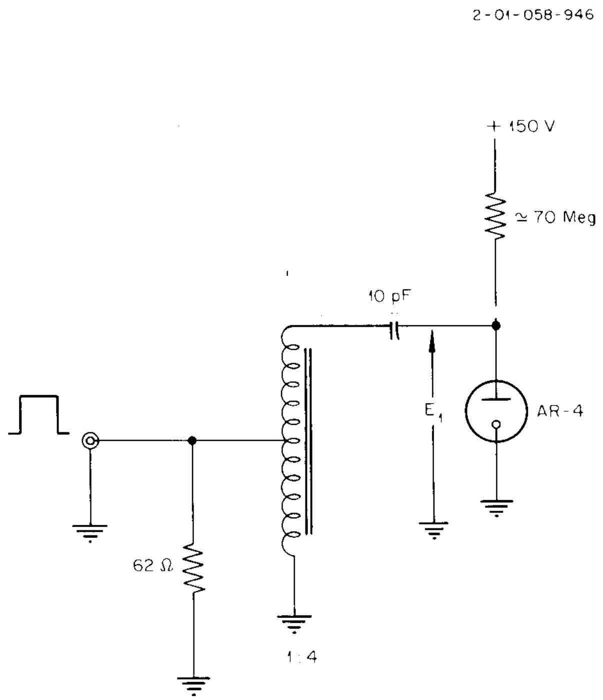

Fig. 3. Electric Schematic for Argon Lamp.

(E_1 in Fig. 3) can be used to drive the lamp. Figure 4 shows the total light output for a 1200-V 18-nsec pulse. The peak light flux is about 5 times as large as for the corona lamp. Spectral analysis of the light output shows that most of the slowly decaying light is in the near-ultraviolet region. Simple optical filters can be used to reduce the decay time significantly with a corresponding reduction in peak light flux by a factor of ~ 13. The pulse shape obtained by using a colored glass filter (Corning No. 3387), which passes wavelengths greater than 4100 A, is shown in Fig. 5. Closer investigation showed that the optical filter is not totally effective in eliminating the slow decay. A single light pulse for a photomultiplier gain of 5×10^8 is shown in Fig. 6, where it can be noted that the lamp continues to emit several photons for many microseconds after the fast rise. More elaborate optical filtering techniques indicate that the residual light in the tail is of the same wavelength as the light in the peak; therefore the ratio of the peak amplitude to the tail amplitude cannot be further improved by optical filtering.

The amplitude stability of both the total light and the filtered light output of the argon lamp is very good. At constant temperature a stability of 0.5% FWHM over a 16-hr period was observed. Although no precise measurement of the temperature coefficient was undertaken, indications are that it is of the order of -0.2%/°C.

The shape of the filtered light pulse is almost independent of the driving pulse width. Increasing the input pulse width from 5 to 20 nsec increases the FWHM of the light pulse only 2 nsec. The same increase in pulse width produces only a 30% change in peak light output. The light pulse shape does change with input pulse amplitude, as shown in Fig. 5. Neither the pulse shape nor the amplitude stability varies for bias currents in the range 0.5 to 2 μA. The peak light output is, however, a slowly varying function of the bias current; hence for good stability a stable bias source is required.

Neon Lamp

Argon and neon lamps designed as indicator bulbs are relatively low-pressure devices (20- to 4-mm Hg). Both types of lamps exhibit the long

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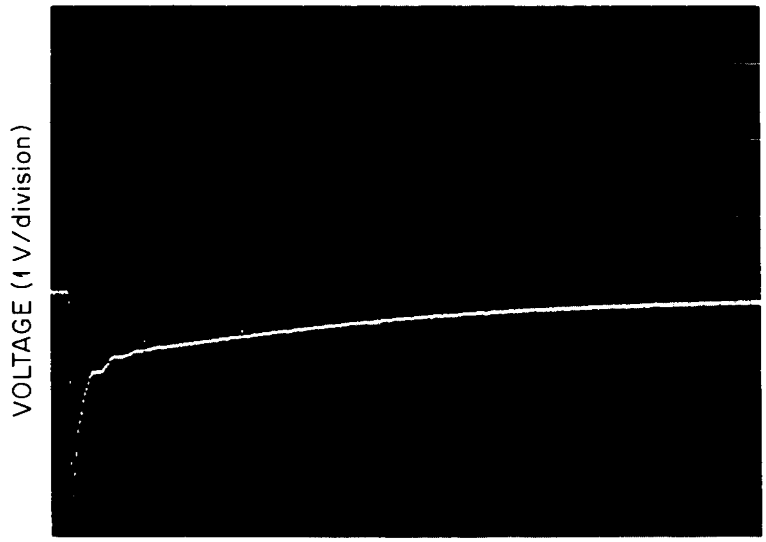

Fig. 4. Total Light Output of Argon Lamp.

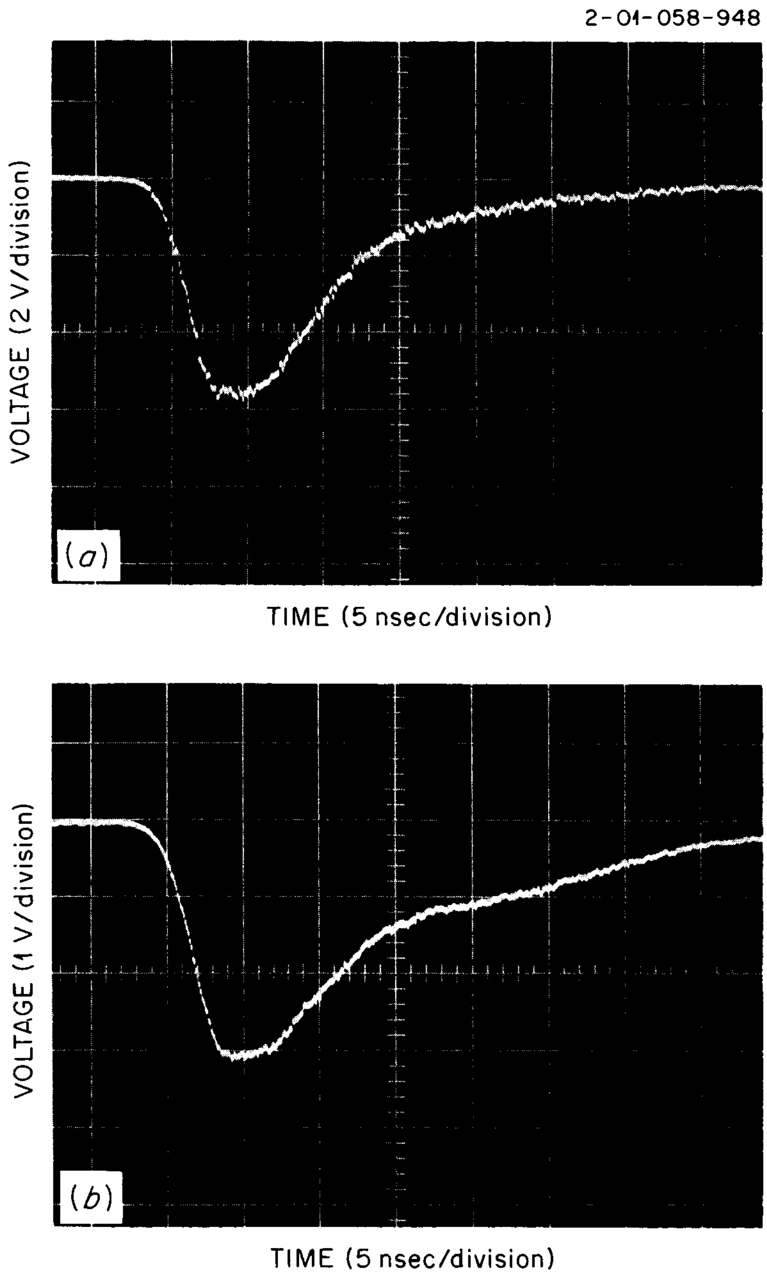

Fig. 5. Filtered Light Outputs Obtained with (a) 1000-V 18-nsec-wide Driving Pulse and (b) 2400-V 18-nsec-wide Driving Pulse.

Fig. 6. Single Light Pulse. Photomultiplier gain 5 x 10^8.

low-amplitude-decay tail. At higher gas pressures the duration of this decay is notably decreased. Figure 7 shows the pulse shape of a high-pressure neon lamp,[4] which consists of tungsten electrodes 0.8 mm in diameter spaced approximately 0.5 mm apart. The neon pressure was 190-mm Hg. The lamp was operated in the same manner as the argon lamp described above. Unfortunately the adjustment of the bias is quite critical, as evidenced by the tendency of the lamp to oscillate as it attempts to reach a stable operating point after each light pulse. No quantitative stability measurements have been made. The precursor to the pulse (see Fig. 7) is due to poor electrical shielding of the photomultiplier. The peak light output is about the same as the filtered light from the argon lamp.

Conclusions

The characteristics of the light sources tested are summarized in Table 1. The corona lamp produces the fastest rise and shortest duration light pulse, but unfortunately the stability is very poor. The argon lamp possesses very good stability, but the long low-amplitude tail may produce difficulties in high-gain systems. The stability of the neon lamp was observed to be much better than that of the corona lamp, and tests are planned to determine whether it is superior to that of the argon lamp.

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[4]Bulb designed by J. H. Todd, Instrumentation and Controls Division.

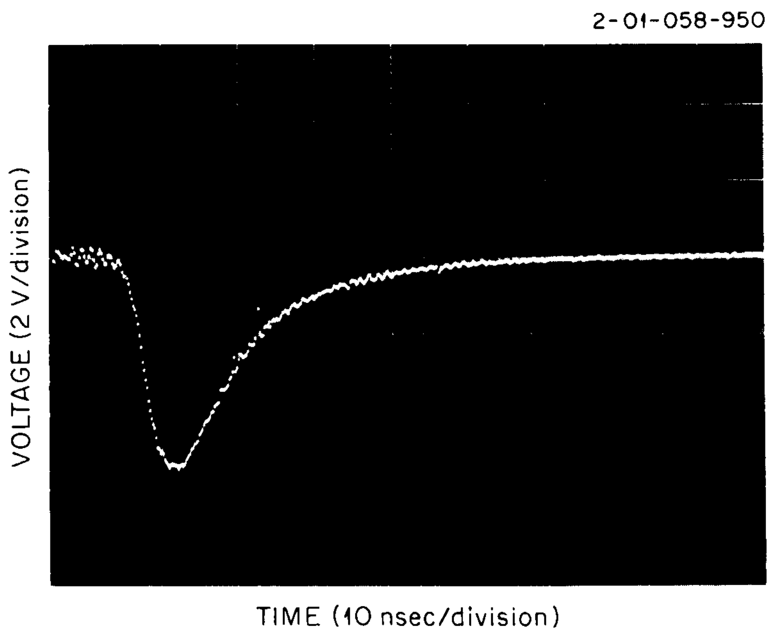

Fig. 7. Pulse Shape of High-Pressure Neon Lamp.

Table 1. Comparison of Characteristics for Corona, Argon, and Neon Light Sources

Characteristics	Corona	Argon	Neon
Light output, lumens/steradian	1×10^{-2} to 11×10^{-2}	2×10^{-3} to 4×10^{-2}	4×10^{-3} to 3×10^{-2}
Light pulse shape,[a] nsec			
Rise time (10-90%)	2.5	3.5	4.0
Fall time (10-90%)	15	25 to 60	25
Light output due to bias current, lumens/steradian		3×10^{-8}	4×10^{-8}
Driving pulse requirements			
Width, nsec	2 to 20	5 to 20	5 to 10
Amplitude	500 to 2000	700 to 2400	350 to 950

[a]Pulse shape as measured at the anode of a 56AVP photomultiplier tube.

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